Risø annual report 2001

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Risø Annual Report 2001

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Risø's activities in 2001 are reported in the following publications: Risø Annual Report (available in Danish and English), Risø Annual Performance Report (Danish) as well as the annual progress reports of the seven research departments (English). All of these publications and more information are available at www.risoe.dk. Printed publications are available on request from the Information Service Department, telephone: +45 4677 4004, e-mail: risoe@risoe.dk, fax: +45 4677 4013.

Content

Beware – Men at work! The renovation of the buildings which are to house Risø's Wind Energy Centre is progressing according to plan.

– We allocate at least 10 per cent of our total expenditure to investments. In this way, we ensure the continued development and adaptation of our research to match the requirements of the surrounding world, which, in turn, is a condition for attracting external financing, says managing director Jørgen Kjems (right).

Vice director Jørgen Honoré (left) is pleased about the highly fruitful synergies of the cooperation between the WTG industry and wind energy research at Risø, and this in spite of delays to another of our major construction projects in 2001, the new wind turbine test station at Høvsøre, which is very much needed by the WTG industry.
– We can now expect the first wind turbine to be deployed for testing by the end of 2002.

The continued need for a strong Risø

The year 2001 got off to an excellent start with Risø being given high marks in an international evaluation. The report from the international panel also supported the course which has been set with the adoption of the strategy for a new Risø which was published in January 2001.

According to the international evaluation "The scientific quality of the research carried out at Risø varies from good to top-class at an international level and the quality of scientific dissemination is very good. In some areas of fundamental research, Risø has a human resource of world class. It is important to maintain this Danish scientific asset."

We are particularly pleased that the international panel found that "overall, Risø's activities are very relevant for industry and for society as a whole".

The evaluation also contained a number of recommendations, many of which have already been incorporated into plans for the coming years.

The evaluation played an important role in Risø's subsequent satisfactory negotiations with the Danish Ministry of Science, Technology and Innovation concerning a new performance contract for the period 2002-2005 for Risø.

Both the contract and Risø's new strategy emphasise the four groups of recipients of Risø's research results: trade and industry, the research community, the educational system and the authorities. Risø's research and other activities are subject to management by objectives and within frameworks and are assessed using indicators for the usefulness of the research results in the four groups of recipients.

From Risø's point of view, the establishment of the new Danish Ministry of Science, Technology and Innovation was a welcome decision by the government. It is an advantage that the universities are all in the same ministry, and that this ministry is at the same time responsible for innovation and development. The fact that our partners here are also finding that they are in good company bodes well for the future cooperation in the Danish research system.

Openness and a broad international outlook have always been the hallmarks of Risø. Risø is a natural part of the European research community. Seen in a European perspective, Risø has an obvious role to play among large institutions which undertake concentrated tasks in the form of targeted programmes and/or the operation of large-scale research facilities.

We will therefore nurture and further develop our role as a player and bridge-builder in the European institutional networks in the coming years. The cooperation agreement with the Paul Scherrer Institute in Switzerland concerning neutron scattering is a good example of this.

Another international dimension is Risø's activities as a research and advisory base for international organisations. Thus, the UNEP Collaborating Centre on Energy and Environment celebrated its 10th anniversary at Risø in 2001 as the developer and disseminator of knowledge and capacity accumulation for selected third-world countries which will thereby be able to act in accordance with the requirements of the international climate conventions.

Risø must also continue the expansion of its cooperation nationally. The Danish Council for Research Policy has carried out an assessment of the role and placing of the government research institutions in the Danish research system. Their report was published just as the present annual report went to print.

We are pleased that the report from the Danish Council for Research Policy emphasises Risø's many strengths: "Risø is a very strong and well-run institution which could contribute significantly to lifting" other Danish institutions. For the Danish Council of Research Policy this is an important reason for considering whether Risø should merge with other Danish institutions, educational establishments or research organisations.

Against this background, it is natural for Risø to have started to lay down the long-term objectives for developing its co-operation with the universities. It is, however, questionable whether Risø can continue to raise the profile of other Danish institutions if Risø is split up. We can see no immediate advantages or benefits from the point of view of resources of Risø's independent status being given up and of the integration of the different parts of Risø with other organisations. On the other hand, we believe the prospects are promising for the continued expansion of Risø's cooperation with other Danish institutions through the coordination of research strategies, educational initiatives and the exchange of intellectual rights. This will improve the application of resources.

Throughout the process, it should be ensured that every step brings clear advantages to partners as well as users. Risø's mission as a national laboratory and the universities' obligations as educational establishments are not and should not be made to look the same. It is also important to remember that the research is being borne by the competences and commitment of employees. It is therefore important that the politicians should allow the institutions sufficient time to find the best possible solutions.

Risø agrees with the council that the possibilities of creating positive synergies though new constellations should be exploited and that, in connection with mergers, it is important that the strongest environment and the best culture become the founding elements. We would be very happy to assist in identifying new organisational models which may strengthen the educational and research environments within the technical and natural scientific fields in Denmark. However, we would also like to ensure that Risø – with its organisation, management and committed scientists – can continue to raise the profile of the Danish research system as expected by The Danish Council of Research Policy.

This brings us to mentioning some of the results which have been achieved in the past year. As we intend to exceed the limits of our knowledge, there is good reason to emphasise

- that Risø has succeeded in conducting the first analyses of the genes expressed in individual plant cells;
- that Risø has similarly succeeded in conducting X-ray studies of the behaviour of individual metal grains during mechanical and thermal processes;
- that it has been demonstrated that, in principle, plastic-based solar cells work.

As regards the creation of a basis for new technologies, it is worth noting

- that Risø has succeeded in developing three-dimensional optical tomographic imaging for use in medical examinations of arteriosclerosis;
- that the nanoplotter is attracting an increasing number of industrial customers;
- that retrospective dosimetry has been carried out using unheated items such as concrete, salt and washing powder;
- that the WAsP wind calculation software has been launched as a general tool.

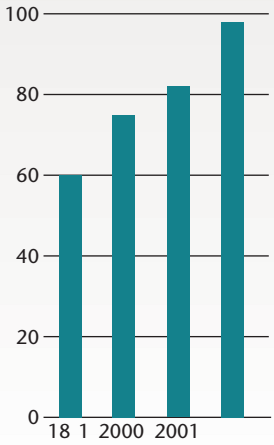
With reference to the establishment and growth of new businesses, it is very satisfactory

- that the development of ceramic SOFC fuel cells has gained further momentum with a marked expansion of the contract with Haldor Topsøe A/S;
- that the synergies between the wind turbine industry and wind energy research at Risø are developing very fruitfully on a broad front even though the establishment of the new and very necessary wind turbine test station at Høvsøre has been delayed;
- that our endeavours to create a development company for bioethanol look set to bear fruit.

The education of scientists has always been an integral part of Risø's activities, and in 2001 Risø has contributed to the MSc education as well as to supplementary education through a wide range of cooperation agreements with universities and other educational establishments in Denmark and abroad. Risø's new contract will lead to continued growth in its contribution to education within a large number of fields.

The nuclear facilities at Risø are being decommissioned and are no longer used for research purposes. Decommissioning takes time, and the plan is for the decommissioning to be undertaken by an independent organisation, Danish Decommissioning, to which responsibility for this task is expected to be transferred in the course of 2002. Risø's activities exist in a pragmatic symbiosis with this decommissioning which will benefit from Risø's competences and research as well as the shared infrastructure. Risø's premises are included in the safety zone around the nuclear facilities, and for a number of years the areas will remain subject to a number of restrictions as a result thereof. This is one of the reasons why the decommissioning should be completed as soon as possible.

Development in revenue from market-controlled acitivities in DKKm



Commercial activities have seen strong growth in the 1998-2001 contract period – which is very much in line with Risø's vision that research must be for the benefit of society as well as Danish industry. The profits generated from these activities have lent further momentum to long-term research.

In this annual report, we present a small selection of Risø's achievements in 2001. A more detailed review of Risø's projects can be found in the Risø Annual Accounts for 2001 as well as in the annual progress reports prepared by the individual research departments.

By way of conclusion, there is every reason to thank all Risø's employees for their excellent efforts in 2001, a year in which results have matched endeavours and been very noteworthy.

Jørgen Kjems
Managing Director

Jørgen M. Clausen
Managing Director of Danfoss A/S,
Chairman of the Board of Governors of Risø

Heads of the wind energy programme, Flemming Rasmussen (left) and Peter Hjuler Jensen (right), and their colleagues at the Wind Energy Department enjoy leaning into a moderate gale. Their department can take a lot of the credit for the fact that every gust of wind all over the world is being utilised ever more effectively. In 2001, the Wind Energy Department set a new record for contract funding by industry, and the commercial activities became the largest source of financing for Risø's wind research.

Energy

The objective is to develop energy technologies which will allow for a continued reduction of the environmental impact of a growing energy consumption over and above the global targets set up in the Kyoto protocol.

Economic milestone for wind energy research

The year 2001 saw record levels of contract funding from industry. Commercial activities became the most significant source of funding of Risø's wind energy research in 2001. This reflects the fact that this research is relevant to Danish industry and to the international market.

Large sales of Risø's WAsP software

An important export article within the field of wind energy is Risø's wind resource estimation software, WAsP. The most important parameter when considering the economy of a wind farm is the wind resource, and WAsP is the industry standard for this.

To some extent this explains why there are currently more than 850 users of the WAsP program which was developed by scientists at Risø. Users come from many countries, primarily in Europe.

Since the development of WAsP over ten years ago, this activity has generated revenue to Risø of up to DKK 2 million annually. In addition to selling software, Risø is also organising courses; a new initiative in 2001 was the introduction

of a certification scheme, where users after passing an exam can become certified WAsP users.

The year 2001 saw the launch of the new IT-based, windpower meteorological dimensioning tool WAsP Engineering. The software was presented at the European Wind Energy Conference in Copenhagen. The program now has more than 30 users, and the first course with twelve participants was held in 2001.

Test station for large wind turbines

Thanks to strong wind conditions and uncomplicated terrain, the future national test site for wind turbines at Høvsøre in Western Jutland will become the world's best site for testing large wind turbines. The four largest Danish companies have already entered into long-term agreements for one test site each. The fifth (and last) site will be leased to different companies under short-term contracts. This test station provides a unique opportunity for research in both wind turbines and also in general atmospheric research. The site is expected to be ready for use in 2002.

Wind can be monitored from space

A reliable assessment of wind resources is the best basis for a national investment in wind power. This is one of the reasons why Risø has now mapped the wind resources in more than 50 countries. This mapping opens doors in connection with the sale of Risø's own products and consultancy services as well as taking Danish wind turbine manufacturers into new markets.

Traditionally, wind resources are mapped through on-site measurements, but in 2001 research scientists gained access to a number of good supplementary tools.

The most recent generation of satellites for observing the Earth can map height differences in the landscape with considerable accuracy. They can also provide a good picture of the so-called roughness of the terrain, i.e. the land cover influence on the wind flow caused by, for example, houses, trees or cliffs. The lower the degree of roughness, the better the conditions for wind power. The wind resources of a given location are dependent both on the force and duration of the wind and on landscape roughness and terrain height variations.

Collecting data from satellites is a considerable advantage. Mapping is less costly, and at the same time it becomes possible to map wind resources in regions which are inaccessible or in which travel is difficult.

Customers test fuel cells

Fuel cells produced at a pre-pilot plant at Risø are now being tested by possible future customers abroad. The plant has been built as part of a comprehensive cooperation project with Haldor Topsøe A/S and is an important element in the development of one of the most important energy sources of the future.

The pre-pilot plant was established in 2001 and is not a commercial facility as such, but is capable of producing fuel cells in such volumes that research will be brought to a completely new stage. The commercial exploitation of fuel cells requires the stacking of many cells in the right way. Future research therefore requires large quantities of uniform cells.

Under the agreement, Haldor Topsøe A/S will have the right to use the results commercially, while Risø is to develop the technology and engage in medium-term and long-term re-

Head of the fuel cell programme Søren Linderoth and a team of researchers and technicians have developed highly effective fuel cells. This progress is based on a long-term research effort combined with a more technological development.

The cells are thin as well as being efficient at low operating temperatures. Thanks to the lower operating temperature, it is possible to connect cells using metal plates and to produce them at costs which are well below the costs of the ceramic materials previously required for cell stacks. Each fuel cell is capable of delivering approx. 1 V and 50 W. To ensure higher voltage and greater power output, the cells are stacked.

Being able to stack the cells in the right way may well lead to the creation of the best commercial fuel cell plant. Thanks to the new pre-pilot plant, Søren Linderoth and his team can mass-produce identical cells and thus test their stacking theories.

search to ensure that Danish solid oxide fuel cells will be capable of defending their leading position in the market.

Chemistry generates electricity

SOFC is an abbreviation of Solid Oxide Fuel Cell, i.e. a ceramic fuel cell. The fundamental principle of an SOFC is the same as that of an ordinary battery, in which the energy from a chemical reaction between air and fuel is converted into electricity. As long as the fuel cell is fed with air and fuel and the "waste products" of the reaction are disposed of, the reaction can continue. The fuel may be, for example, pure hydrogen, natural gas, biogas or reformed petrol and the waste products are primarily water and carbon dioxide. The Danish Energy Research Programme, Elkraft System, Eltra, and EU grant Risø´s research in solid oxide fuel cells.

Both batteries and SOFCs generate direct current. In order to achieve a sufficiently high voltage before the direct current is converted into alternating current, a large number of cells must be connected in series in a cell stack.

In other words, manufacturing one good cell is far from sufficient. It may well be the ability to stack the cells in the right way which creates the best commercial fuel cell plant.

Forward-looking patent strategy

Fuel cell research has been conducted at Risø since the 1980s, and a number of patents have been taken out in this field. Several of these patents are included in the basis for the new cooperation with Haldor Topsøe A/S. So far, the agreement covers five years.

For the tenth year, the UNEP Centre at Risø is presenting an internationally recognised team in the fight for a better global environment.

This year, team captain John M. Christensen (top left) has strengthened the UNEP team's position in the international championship league by being appointed member of the Bureau of IPCC, the UN Intergovernmental Panel on Climate Change.

The agreement may serve as a model for cooperation with other companies in future. The cooperation concerning the SOFC project is a very long-term cooperative research project. The interest shown in the project by a company such as Haldor Topsøe A/S is largely attributable to the fact that Risø holds a number of patents which the company will in this way be able to use commercially.

The agreement with Haldor Topsøe A/S secures the investment of at least 35 man-years per year at Risø within SOFC research over the next five years. In the event of Danish SOFC technology becoming sound business for the company, revenue will be generated by Risø in the form of licence fees.

Plastic solar cells

The world's best semi-conductor solar cells convert approximately one third of the sun's energy into electricity. In theory, they may be outshone by plastic cells which may also be far cheaper. Risø is now focusing on the development of solar cells made exclusively from plastic. The workings of the principle were demonstrated in 2001.

Solar cells generate electricity without polluting the air and without contributing to the greenhouse effect. However, the price of one kWh must be reduced to a tenth of its present level before solar cells can compete on price with conventional energy sources. This price reduction can be achieved through the use of plastic materials. If the research

is successful, the plastic cells may become more efficient than conventional solar cells. At the same time, the raw materials and the processes are cheaper than for semi-conductor materials.

Another year of research will show whether it will make sense to continue and step up endeavours. If that is the case, it will be another few years before a realistic idea can be formed as to how effectively plastic solar cells will be able to use the sunlight. Commercial production is well into the future.

New energy success underway

Bioethanol is a CO_2-neutral fuel which can be added to petrol and replace diesel. Research in 2001 has shown that bioethanol can be manufactured at a competitive price in combination with the production of biogas. A new energy success story not unlike the wind turbine one may be in the pipeline. So far, bioethanol has been too expensive relative to petrol and diesel. However, the situation may soon change through combining the production of ethanol with the production of biogas. The two processes utilise each other's waste products, do not produce waste water of any significance and therefore make it possible to produce both ethanol and biogas at a reasonable price.

The new combined process has been developed by Risø and the Technical University of Denmark. While bioethanol is traditionally made from sugar cane in, for example, Brazil, the Danish process is based on wheat straw which may thus become a possible crop for the production of liquid fuel for cars, buses and lorries. In 2001, Risø progressed considerably in its efforts to establish a development company for bioethanol.

Climate policy with an eye on costs

In many countries across the world, there has been an increasing level of interest in doing something about the emissions of greenhouse gases. The greenhouse effect – the fact that pollution created by man is causing global warming – has been documented by leading international climate scientists.

This has meant that the UNEP Collaborating Centre on Energy and Environment (UCCEE) at Risø has had an important role to play. UCCEE is a collaborating centre of the United Nations Environment Programme (UNEP). Environmental economics is a central area of activity for the centre which is co-financed by UNEP, the Danish International Development Assistance (Danida) and Risø itself.

In 2001, the centre has documented that in many places in the world it is possible to reduce emissions of carbon dioxide, the dominating greenhouse gas, at little cost. However, it will typically be a good idea to involve the developing countries which cannot themselves afford even modest additional environmental investments. According to the international Kyoto agreement, rich countries helping poorer countries with such investments can offset the reduction in emissions against some of their own obligation to reduce domestic emissions.

No such agreement has ever been made before. Much work will therefore go into laying down the terms and procedures which are to apply to the trade in pollution quotas between countries. Since the establishment of the UCCEE Centre in 1991, the centre, which today has a staff of twenty employees of different nationalities, has made an ever-increasing contribution to this work.

2001 marked anniversary of the UCCEE Centre

In addition to marking its 10th anniversary, in 2001 the centre also celebrated the fact that a number of employees submitted scientific articles which may leave their mark on the world's climate policies. This was through contributions to the report "Climate Change 2001 – Mitigation", which is the UN climate panel's recommendation on reducing the increasing emission of greenhouse gases and of course in a way which ensures that costs are kept to a minimum.

Employees from the centre have also undertaken a number of studies for international organisations of how different countries may reduce emissions. This work has included a method on how to calculate the reduction in emissions achievable through alternative projects.

Industrial technology

The objective is to develop new materials and components which can reduce resource consumption and minimise the impact on the environment and which, at the same time, can form the basis of the development of products that are capable of creating, attracting and developing knowledge-based industry in Denmark.

Centre for Fundamental Research: Metal Structures in Four Dimensions

Financed by the Danish National Research Foundation, Risø has established a centre for research in metals. A key instrument at the centre is a new 3D X-ray microscope. In 2001, this microscope was used, for example, to study the changes occurring in individual grains deep inside metals while they are being deformed. The results revealed that the existing models are not adequate to describe the findings, and that new models must be developed on the basis of the new data. The Foundation has made DKK 36.5 million available to the centre over a five-year period. The centre was established on 1 August 2001.

Swiss gateway to neutron-scattering experiments

A framework grant and a cooperation agreement with a Swiss institute imply that materials research scientists at Risø will in future also be taking part in leading-edge research into the phenomenon superconductivity and its practical applications. The closure of the DR3 research reactor was a threat to Risø's position and cooperation with leading international research centres. As a result of the closure of DR3, research scientists would no longer have access to neutron radiation which is an absolute necessity in experimental superconductivity research.

Thanks to the cooperation agreement, Risø's research scientists will have access to neutron radiation at the Paul Scherrer Institute in Switzerland. In return for this access, Risø is obliged to transfer three instruments to the Swiss institute.

The first instrument, the RITA II spectrometer, has already been transferred and has produced its first results. This brand new instrument is designed for high-precision measuring of atomic structures and vibrations through the use of neutrons.

Another two instruments will be transferred, in 2002 and 2003 respectively.

New funding for superconductor research

Superconductivity – the ability to conduct electrical current with no loss of energy – has been the focus of international attention since the discovery in the mid-1980s that superconductivity could take place at temperatures higher than absolute zero.

Understanding the interaction between superconductivity and magnetism is extremely important, both for fundamental research and for the technological applications. Risø's activities focus on this interaction and on the development of new superconductor materials.

Nobody is perfect. It is the little imperfections that produce the strength as is the case with metals. The staff of Risø's Materials Research Department are shown here demonstrating a nano metal with a defect that has given rise to new properties. This is a telling symbol of the new, interdisciplinary research field of nano technology – the new focus area of Risø. Our contribution is to develop new materials and components at nano scale which can form the basis for the development of products that are capable of creating, attracting and developing knowledge-based industry in Denmark.

Artificial muscle in action: Some day in future robots with artificial plastic muscles will be arm-wrestling with human beings. Head of programme Kristoffer Almdal is, however, still capable of defeating today's toy robots. His colleagues, from the left, are senior scientist Sokol Ndoni, laboratory technician Tanja Mazur (Optilink A/S), post doc. Lasse Bay and Ph.D. student Carina Koch Johansson.

The artificial muscles (polymeric actuators) which have been developed in cooperation with Danfoss A/S and the Technical University of Denmark are now reproducible. A silicone rubber actuator with intelligent electrodes has been produced in both a single-layer and a multi-layer version. It is capable of lifting 20 times its own weight.

A new five-year framework grant from the Danish Technical Research Council has ensured that this can take place in a broadly based collaborative project between Risø, the Technical University of Denmark and the University of Copenhagen, and that Danish companies are ready to exploit the results.

Nano-scale fakir bed can deter cells

Creating plastic surfaces capable of rejecting cells and thus of keeping clean for a long time is of interest to manufacturers of contact lenses and prostheses. »The changes can be made at such miniscule level that they are of no importance to the intended use of the objects, but nevertheless have a significant capacity for deterring cells.«

Experiments undertaken by the Danish Polymer Centre, where Risø and the Technical University of Denmark collaborate, have shown that the structure of a surface plays a key role in determining whether and how human cells will grow on a surface. Initially, the research scientists have used this knowledge to produce surfaces that stimulate cell growth. The next step is to achieve the opposite result: finding surfaces that reject cells and, thus, are ideal for contact lenses, prostheses and other items where the specific objective is to avoid cell growth.

The variation in height created in the plastic surface is just a few nanometres (one nanometer is 10-9 metre). Larger variations in height would probably not have the same effect as regards the stimulation or inhibition of cell growth.

In the human body, cells grow on structures known as collagen. Collagen serves as a kind of scaffolding in the form of connective tissue which cells cling to and move around on.

Risø's research scientists have previously succeeded in making an impression of collagen. The result is a mould which can be filled with plastic to create a surface which has exactly the same surface contours as collagen. Preliminary experiments suggest that cells grow better on this surface than on a smooth surface made of the same type of plastic.

This knowledge has given researchers the idea of finding surfaces that are capable of inhibiting cell growth. The preliminary experiments undertaken in 2001 indicate that it is possible to achieve this effect by creating a nano-size "fakir bed" for the cells.

Nanoplotter produces lens for optical tweezers

Using a special lens it is possible to funnel the light of a laser beam and make the beam so focused that it can be used for

trapping and manipulating individual cells. This is called a pair of optical tweezers. Risø has now developed a set of dynamic methods that allow several such tweezers to be used simultaneously, whereby it is possible to manipulate many small particles at the same time.

This new development will further expand the scope for using optical tweezers within a wide range of areas in the fields of medical and biological research.

The precision of the lens used to focus the light must evidently be high. Risø has developed its own instrument, a so-called nanoplotter, which generates the optical phase masks that are used for focusing the light with a level of precision that is better than 100 nanometres.

In addition to its in-house use at Risø for research purposes, the nanoplotter is in demand with other institutions and companies, and for this reason the staff will have to be increased. Besides a number of Danish companies, the list of customers includes the US space agency NASA.

Early warning against thrombosis

Within the past couple of years, it has become possible to record images inside blood vessels. Together with medical doctors at a number of hospitals, Risø's research scientists have added a new dimension to this: scanning the structure of the very wall of the blood vessel.

This method allows medical doctors to "see" structures with a clarity exceeding existing methods. The objective is to make it possible for medical doctors in future to diagnose vascular disorders in, for example, the coronary artery far earlier than is possible today. Through prophylactic action, the risk of developing thrombosis may consequently be reduced for a number of patients.

The method is based on the OCT principle – Optical Coherence Tomography. When light is directed towards the wall of a blood vessel, a small amount of the light will be reflected by the internal structures. The light thus reflected can be detected (recorded).

The biggest challenge of using the OCT principle for examining blood vessels is that it is necessary to produce an optical fibre system that can both emit light and detect the light reflected – and at the same time fit the endoscopes used by medical doctors for, e.g., heart examinations. Not only must the system be compact and precise, it must also be capable of generating images at high speed.

Apart from its use in connection with blood vessel examinations, Risø's research scientists are also working with a number of other biomedical applications for the OCT principle, examples of which include eye and skin diseases.

Biological method suited for plastic analyses

In cooperation with Coloplast A/S and FORCE Technology, Risø is working at transferring the OCT principle for industrial applications. When light is directed towards plastic, a small amount of light is reflected by the internal structures. The light thus reflected can be caught and detected by an OCT system. In this way, the thickness of a 1 mm plastic film can be determined with a precision of 1/100 mm.

If the material is composed of several layers, it is possible to use this method to determine the thickness of each layer – even if the material is not transparent. The use of this method is, however, restricted to materials with a thickness of 3 mm or less.

Coloplast is currently considering the introduction of OCT for the continuous measuring of plastic film thickness. During production, the plastic is heated (extruded) and this is one reason why it may be difficult to measure the thickness. With the OCT method, the measuring equipment is not in physical contact with the material, a fact that makes the method ideal for this type of measuring. At the same time, the OCT principle meets the requirements of Coloplast as it offers a reliable and precise method.

Danish debut in technology foresight

Biochemical and optical sensors and MEMS (micro electromechanical systems) are the three top scorers in the first Danish study based on "technology foresight". Scientists and industry alike expect all three types of sensors to experience major breakthroughs and high growth in the coming ten to fifteen years.

In collaboration with the Danish Sensor Technology Center A/S, Risø has carried out an assessment of the potential of the many different types of sensors that are rapidly being developed in these years.

A total of 174 international experts from the industrial and research communities have completed a questionnaire in which they were asked to assess the technological and commercial prospects in the period up to 2015 and, furthermore, to assess the barriers that may prevent this potential from being realised.

While highly ranking the potential offered by biochemical and optical sensors as well as MEMS, the study also stresses that chemical sensors and systems incidental to the sensor as such will be growth areas. The study has been supplemented by a number of qualifying comments specifically relating to conditions in Denmark.

The replies have been compared with assessments from a number of workshops with participating Danish and international experts and have also been compared with literature studies. The findings have been presented to the sector.

The systematic approach to technological development inherent in technology foresight is being adopted by an increasing number of countries. The study of the sensor area is the first Danish study of this nature. Risø expects that the study can serve as a prototype for several similar studies targeted at other sectors.

Master of light, gaffer and light designer would be appropriate titles for Jens-Peter Lynov as the department headed by him focuses on harnessing light so that it can be used in a multitude of useful applications: Surgery, diagnostics, processing of materials, high-precision measuring, communications and data storage.

In 2001, the Optics and Fluid Dynamics Department had its busiest year ever filing patent applications, being responsible for eleven of a total of seventeen applications filed by Risø. At the same time, the departmental staff succeeded in publishing the greatest number of international papers in the three most recent years.

Bioproduction

The objective is to develop methods for mapping gene products in plants from gene to function with a view to producing tailored raw materials for food production, medicine and materials from plants in the environment of the future.

Breakthrough for single-cell analysis

A new technology developed at Risø in 2001 makes it possible to sample individual plant cells for analysis.

The analysis is carried out using a pipette with an aperture diameter of only a few micrometres. As it is not possible to follow the work of the pipette with the naked eye, it is necessary to monitor its work under the microscope via a computer screen. By working at such a high level of magnification it is possible to analyse the individual cell. The method is consequently called single-cell analysis.

With the microscopic pipette the contents of a single cell from a barley leaf can be sampled. The sample is used for analysing, for example, the defence mechanism of barley against mildew spore.

Considerable variation can be observed in the individual cells of a leaf attacked by mildew spore. Some cells have

Dr. Jens Kossmann, head of the Plant Research Department, intends to bring Risø's plant research activities closer to the international market. Jens Kossmann came to Risø in 2001 from the Max Planck Institute of Molecular Plant Physiology in Berlin.

Industry and the academic community might be worlds apart, but Jens Kossmann, who has experience from both, is certainly capable of uniting them.

completely succumbed to the attack, others have not yet been attacked, while others have, with varying degrees of success, been capable of repulsing the attack. Using traditional methods for taking a sample from a leaf, the result is a mixture of various cell types and it will reflect an average of these differing situations.

Typically, plant research scientists are not interested in average values, but rather in the precise difference between the resistant cells (cells that have repulsed the attack) and the cells that have succumbed.

It is conceivable that in this way it will be possible to identify the very mechanisms which are responsible for the plant cells' capability of resisting mildew spore attacks. Thanks to this new approach, research scientists expect to increase the basic understanding of the resistance phenomenon. It may pave the way for completely new methods for fighting the spores.

Commercial perspectives

Within the field of plant research, Risø has concluded a cooperation agreement with DLF-Trifolium, and many of the other plant research projects offer scope for cooperation with industry – with a little patience. Industry has been through a period of considerable uncertainty. Where just five years ago there were fifteen to twenty major companies, now only a handful remains following a wave of mergers. At the same time, these agrochemical companies continue to see change as they are increasingly shifting their focus to biotechnology. Once this transformation process is over, new commercial perspectives will become apparent for Risø's research activities within the plant field.

Protection against radioactivity and radiation

Risø is a Danish knowledge centre within the fields of radiation safety and radioactivity in the environment and carries out research into how nuclear methods can be applied within industrial and research communities.

Table salt stores information on radiation doses

A bowl of ordinary table salt stores information on the radiation dose to which it has been exposed. The same goes for many other everyday materials such as washing powder, bleaching agents and concrete.

This discovery is the result of an EU-subsidised research programme on the retrospective (i.e. relating to the past) determination of radiation doses after accidents involving ionising radiation.

Optically stimulated luminescence (OSL) exploits the fact that many materials store radiation energy which can subsequently be released as a light signal. The stronger the light signal, the higher was the radiation dose to which the material was exposed.

The studies undertaken at Risø in 2001 have shown that, for example, table salt, washing powder, bleaching agents and other household articles can be used for retrospective dosimetry. Materials of this type are found in all homes and at most workplaces and can thus be used to measure the radiation dose soon after a nuclear accident, irrespective of where and when the accident occurred.

Another important result achieved in 2001 within retrospective dosimetry is that for the first time it became possible to measure the stored radiation dose in concrete and mortar. This was made possible by analysing the OSL signals emitted by individual grains of quartz found in these materials. For this project, Risø has developed a new laser-based OSL instrument where a thin laser beam automatically focuses on the individual quartz grains in the sample and measures the OSL signal emitted by each grain. Using this technique, the grains reset by daylight during the production of concrete and mortar can be identified. These grains provide the most accurate measurement of the radiation dose.

Accurate control of radiation therapy

The OSL method was further developed in 2001 for the purpose of determining the doses to which patients are exposed during radiation therapy. The final objective is to be able to measure the radiation dose targeted at a specific part of the patient's body with a high degree of accuracy during radiation. The first version of the measuring probe consists of a small crystal piece of a suitable OSL material which is fitted to the end of a very thin optical fibre. The thin probe can, without major surgical intervention, be directed to the part of the body that needs to be irradiated.

Radiation measuring equipment sells well

Risø's luminescence dosimetry equipment has undergone significant development in 2001. The equipment can be used both for measuring radiation doses following nuclear accidents and for archaeological and geological dating. With sales rising considerably in 2001, equipment was supplied to approximately twenty research laboratories all over the world. Total sales rose from DKK 7 million in 2000 to more than DKK 10 million in 2001.

Chernobyl accident is still being felt in the Baltic area

The level of radioactive caesium after the Chernobyl nuclear accident has fallen more slowly in the Baltic Sea than in other sea areas. This is mainly attributable to the fact that the water is renewed more slowly in the Baltic Sea. Another

To Marianne Aznar (right) and her colleague Kristina Jørkov Thomsen, salt is not just something you add to food. This is because they know that ordinary table salt as well as washing powder and detergents store information on the radiation doses to which they have been exposed.

So, together with their colleagues at the Radiation Research Department, they have developed a method for retrieving this information. They are thus able to measure radiation levels immediately after a nuclear accident irrespective of where and when it occurred.

factor is that radioactive caesium has been entrapped in seabed materials in the Baltic Sea. It appears that part of this radioactive caesium is now slowly being released, and the overall status is that there are still relatively high levels in the water which, however, do not imply any health risk to animals or human beings.

The monitoring of Danish waters provides an overview of the origin of the radioactive contamination. By comparing the levels of contamination in a series of water samples with the salinity, it is possible to determine whether the contamination stems from the Baltic Sea or from the North Sea. This method exploits the fact that the salinity in Danish waters falls gradually when moving eastwards from the saline water of the North Sea to the relatively fresh water of the Baltic Sea.

The findings show that radioactive caesium is transported through Danish waters from the Baltic Sea to the North Sea and that radioactive technetium from the English Sellafield reprocessing plant can be traced moving in the opposite direction.

Risø Decommissioning

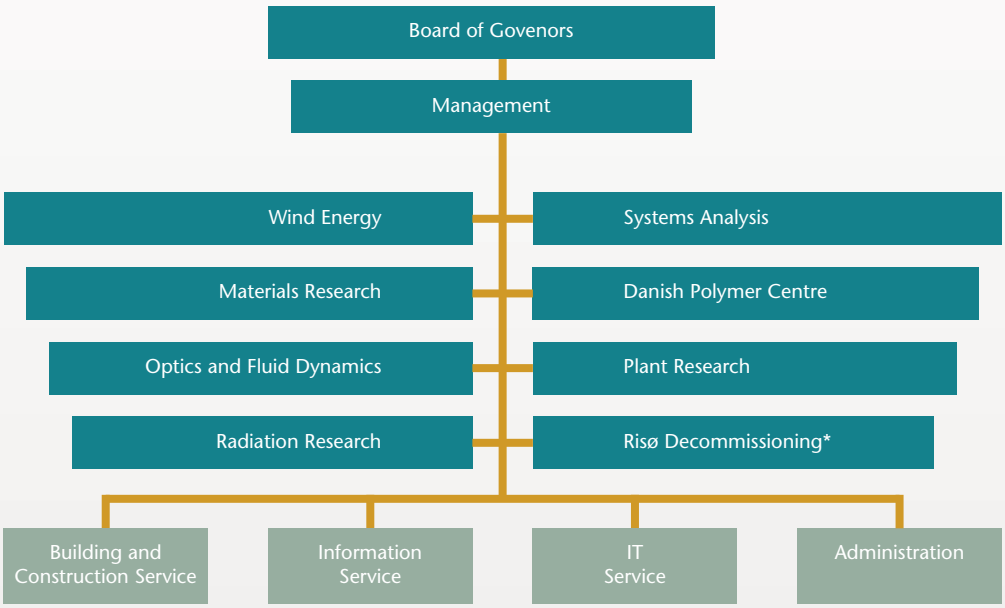
Risø Decommissioning was established in 2001 as a department with special status within Risø. The department is working closely with Danish Decommissioning on the planning of the coming decommissioning of Risø's nuclear facilities.

Following a request from the then Danish Ministry of Research and Information Technology, in the year 2000 Risø appointed a working group charged with preparing a common recommendation concerning the decommissioning of the nuclear facilities at Risø. In 2001, this recommendation was supplemented with additional analyses, including a new review of estimated costs, the alternatives to decommissioning and considerations concerning a repository.

According to the Danish Planning Act, an environmental impact assessment (EIA) must be conducted in connection with decommissioning. This means that regional planning must be based on a particular EIA.

The Greater Copenhagen Authority is the EIA authority in the Greater Copenhagen area and is in charge of these activities. Regional planning is expected to take approximately one year and comprises two public hearings. Risø has contributed voluminous material for use in connection with a systematic description of the decommissioning project. The first public hearing was held in February 2002.

Organisation



* Will according to plan be transferred to an independent organisation in 2002.

Board of Governors

Risø is managed by a Board of Governors consisting of ten members. The Chairman and the other members of this Board are appointed by the Minister for Science, Technology and Innovation. Of these members, two members are elected by and among the employees at Risø.

Jørgen Mads Clausen, Managing Director
Danfoss A/S, Chairman

Birthe Skands, Director
VIKAS A/S
(Vice Chairman from 1 March 2002)

Povl Skovgaard, Director
Vice Chairman (until 28 February 2002)

Per Buch Andreasen, MD, Dr.Med.Sc.
Copenhagen University Hospital Gentofte

Knut Conradsen, Vice-Rector, Professor
Technical University of Denmark

Jørgen Elikofer, Head of Department, President's Office
Danish Metalworkers

Agnete Gersing, Deputy Permanent Secretary
Ministry of Finance

Torben Mikkelsen, Senior Specialist
Risø National Laboratory
Elected by Risø staff (from 1 June 2002)

Jens Olsson, Research Technician
Risø National Laboratory
Elected by Risø staff (until 28 February 2002)

Annette Toft, Head of Department
Danish Agricultural Council

Ulla Röttger, Director
Amager Incineration Plant

John Agertoft Hansen, Purchaser
Risø National Laboratory
Elected by Risø staff (from 1 March 2002)

Lisbeth Grønberg, LL.M.
Risø National Laboratory, Secretary of the Board

Management

Jørgen Kjems, Managing Director

Jørgen Honoré, Deputy Managing Director (until 30 April 2002)

Lisbeth Grønberg (Acting Deputy Managing Director from 1 May 2002)

Heads of departments

Wind Energy
Erik Lundtang Petersen

Materials Research
Robert Feidenhans'l (from 1 June 2001)
Allan Schrøder Pedersen (acting until 31 May 2001)

Optics and Fluid Dynamics
Jens-Peter Lynov

Radiation Research[1]
Benny Majborn

Systems Analysis
Hans Larsen

Polymers
Klaus Bechgaard (acting from 1 December 2001)
Ib Johannsen (until 30 November 2001)

Plant Research[2]
Jens Kossmann

Risø Decommissioning
Mogens Bagger Hansen

Building and Construction Service
Freddy Mortensen

Information Service
Birgit Pedersen, Head of Department
Leif Sønderberg Petersen, Public Relations Officer

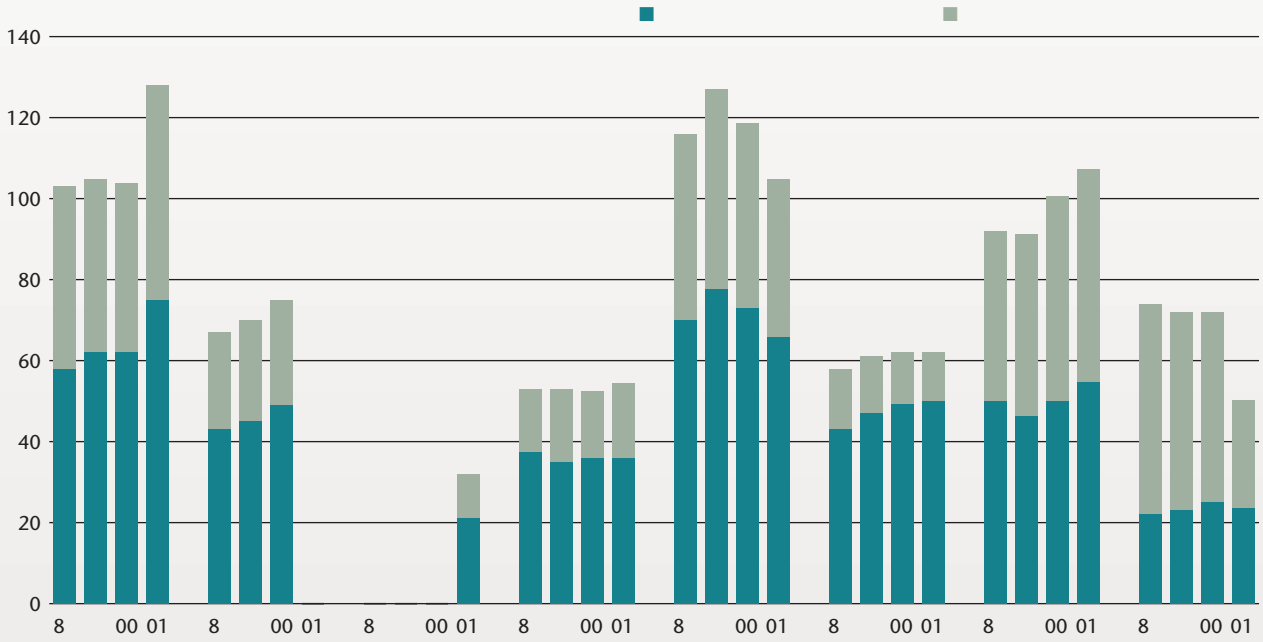
IT Service
Erik Kristensen

Administration
Lisbeth Grønberg, Company Secretary
Minna Nielsen, Finance
Ulla Rasmussen, Personnel
Hanne Troen, Safety

1. New name from 1 January 2002. Former name was Nuclear Safety Research

2. New name from 15 May 2001. Former name was Plant Biology and Biogeochemistry.

Staff with research obligations



Personnel

The most important prerequisites for living up to Risø's mission and for realising Risø's strategy are the competences, creativity and commitment of its personnel. We are striving to provide good career prospects for research scientists, which is reflected in an increase in the number of man-years allocated to research professors, research specialists and research scientists from 2000 to 2001. On the other hand, the number of man-years allocated to scientists/post-doctoral research fellows and PhDs has fallen from 2000 to 2001 due to a delay in recruitment. Endeavours are going into reversing this trend by focusing more on the recruitment of these staff groups. 2001 saw the introduction of a new recruitment strategy which included a new advertising concept, greater visibility of career opportunities at Risø as well as of Risø's teaching activities at universities and other institutions of higher education.

The share of employees with research obligations has increased slightly from 2000 to 2001. Within the departments, resources are being moved from low-priority areas to high-priority areas, and new employees are taken on in high-priority areas in line with Risø's strategy.

Education of scientists

PhD degrees awarded in 2001

Materials Research Department
Marianne Glerup
Lotte Gottschalck Andersen
Erik Mejdal Lauridsen
Lene M. Pedersen
Kenneth Petersen
Tejs Vegge

Optics and Fluid Dynamics Department
Sune Lomholt
Fridolin Okkels
Lars Thrane
Christian Linneberg (industrial PhD)

Systems Analysis Department
Klaus Skytte

Polymers Department
Guggi Kofod
Carsten Svaneborg
Bo Wegge Laursen

Plant Research Department
Henrik Hauggaard-Nielsen
Christian Sig Jensen
Helene Bendstrup Klinke
Tina Tandrup Poulsen
Katja Salomon Johansen

Prizes, appointments and awards in 2001

Upon the recommendation of the (1) Department of Physics and (2) Informatics and Mathematical Modelling, the Technical University of Denmark has appointed Senior Research Specialist Jens Juul Rasmussen Adjunct Professor within the area of non-linear science at the Technical University of Denmark for a five-year period starting on 1 December 2001.

Henrik Bindslev, Head of Research Programme on Plasma and Fluid Dynamics, has been appointed member of the Scientific Advisory Committee (Fachbeirat) at the Max-Planck-Institut für Plasmaphysik in Garching.

Research Professor Per Michael Johansen has been awarded the Danish Dr.scient. degree for his thesis "Linear and non-linear space-charge field effects in photorefractive materials". The public defence took place on 18 May 2001 at the H. C. Ørsted Institute at the University of Copenhagen.

Finance

Operating statements 1999-2002	1999	2000	2001	2002	2002
DKKm, excluding VAT in current prices	Accounts	Accounts	Accounts	Budget Risø [1]	Budget RD [2]
Revenue	**509.2**	**517.0**	**578.7**	**565.4**	**69.0**
Government appropriations					
Contract with Ministry of Research and					
Information Technology	264.3	267.5	284.9	245.3	65.6
Additional appropriations, cf. contract	0.0	10.0	28.4	0.0	0.0
Restrictions on available funds 2000	0.0	(3.1)	0.0	0.0	0.0
Other contracts	171.6	161.9	167.4	206.2	0.0
Market-controlled activities	58.6	76.6	98.0	102.6	3.4
Services Risø / DD	0.0	0.0	0.0	11.2	0.0
Market-controlled, silicon	14.7	4.1	0.0	0.0	0.0
Current expenditure	**470.8**	**479.6**	**506.6**	**501.0**	**69.0**
Wages and salaries	290.5	297.6	301.5	305.5	26.9
Operating costs	162.6	182.0	185.3	195.5	23.5
Reactor fuel, disposal	17.8	0.0	19.8	0.0	18.6
Operating profit	**38.3**	**37.4**	**72.1**	**64.4**	**0.0**
Investments	38.0	57.2	53.7	75.4	0.0
Investment pool	23.8	21.8	12.8	21.4	0.0
Wind energy centre, etc.	0.0	16.8	22.5	32.0	0.0
Departmental investments	14.2	18.6	18.4	22.0	0.0
Net profit	**0.3**	**(19.8)**	**18.4**	**(11.0)**	**0.0**

Note 1 : Excluding the nuclear (decommissioning) activities which are expected to be transferred to Danish Decommissioning on 1 January 2002. The Budget for 2002 was prepared before the appointment of the new Danish government and thus does not include savings associated therewith.

Note 2 : RD = Risø Decommissioning.

Environment and safety

Safety levels at Risø are high. It is, however, the aim of Risø's safety policy to improve standards even further. We want safety initiatives to be preventive and safety issues to form a natural part of our daily work. We also want to see a clear connection between the responsibilities for management and safety.

Green Accounts are prepared by Risø each year. The Green Accounts provide an overview of Risø's compliance with legislation and approvals relating to safety and the environment, our consumption of resources, emissions to the surrounding environment and health effects on staff as well as staff absences due to illness.

In 2001, emissions to the surrounding environment and the health effects on staff were generally below the statutory limits or 'good practice' values. However, within a number of areas, Risø's environmental figures have increased in 2001 relative to 2000. Examples are the number of fire alarms, consumption, waste and waste water.

The maximum limit for the discharge of waste water was exceeded on four occasions in 2001. The most significant instance was seen in connection with heavy rainfall in the autumn where hourly volumes of 96 cubic metres per hour were discharged, while the maximum limit is 80 cubic metres per hour. The total waste-water volume is well below the permitted levels.

Water consumption has increased in the past couple of years. In 2001, it became clear that the reason was a leak from a soft water pipe. Risø therefore expects a significant fall in the consumption of soft water in 2002.

In 2001, the number of fire alarms was higher than for 2000. This is due partly to changes to the method of calculation and partly to a continued high level of construction activities.

In the past few years, Risø has put a lot of effort into fire prevention. Risø's objective for 2001 was to improve the average fire risk level from 2.7 to 2.5, which was achieved.

The nuclear facilities were closed down in 2000, for which reason work in 2001 has only included activities in connection with the decommissioning, planning and application for approvals for the decommissioning of all nuclear facilities at Risø. The collective effective dose has therefore been lower in 2001 than in previous years.

Heating and natural gas consumption was higher in 2001 than in 2000. This is due to the closure of reactor DR3, as surplus heat from this reactor was previously used for heating Risø's buildings. In 2001, only natural gas has been used for heating.

Mission
Risø's mission is to promote value-generating and environmentally sustainable technological development within the areas of energy, industrial technology and bioproduction through research, innovation and consultancy.

Vision
Risø's research shall *push the limits* for the understanding of nature's processes and interactions right down to the molecular nano-scale level.

The results achieved shall *set new trends* for the development of sustainable technologies within the areas of energy, manufacturing industry and biotechnology.

The efforts made shall *benefit* Danish society and lead to the development of new large industries.

Risø's activities in 2001 are reported in the following publications: Risø Annual Report (available in Danish and English), Risø Annual Performance Report (Danish) as well as the annual progress reports of the seven research departments (English). All of these publications and more information are available at www.risoe.dk.

Printed publications are available on request from the Information Service Department, telephone: +45 4677 4004, e-mail: risoe@risoe.dk, fax: +45 4677 4013.

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